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# (54) Process for producing wiping nonwoven fabric.

(57) A nonwoven fabric useful for disposable towels, napkins, wet tissue papers, wipers, and dustcloths, is produced by laminating a paper sheet comprising pulp fibers and having a wet tensile strength of 0.04 to 1.5 kg/25 mm on a surface of a filament web made from a plurality of filaments randomly accumulated on each other; and applying a plurality of water jet streams toward the paper sheet of the resultant laminate under a pressure sufficient to allow the water jet streams to penetrate the filament web through the paper sheet and to cause the pulp fibers and the filaments to intertwine with each other, thereby forming a nonwoven fabric.

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## BACKGROUND OF THE INVENTION

### 1. Field of the Invention

The present invention relates to a process for producing a wiping nonwoven fabric. More particularly, the present invention relates to a process for producing a wiping nonwoven fabric useful for disposable towels, napkins, wet tissue sheets, wipers and dustcloths.

### 2. Description of the Related Art

It is known that a conventional nonwoven fabric usable as a wiping material for example, a disposable towel or napkin is produced by forming a dry pulp sheet composed of pulp fibers that accumulate in layers to form a bulky sheet, and the dry pulp sheet is then impregnated with water or a chemical liquid. However, the above mentioned conventional wiping material is disadvantageous in that after impregnation with water or the chemical liquid, the resultant wet sheet exhibits a poor wet tensile strength and thus is easily broken during use thereof. Another wet wiping material made by forming a nonwoven fabric that is produced by accumulating hydrophilic rayon fibers in layer and then bonding the rayon fibers to each other at crossing points thereof with a rubber type binder, and impregnating the nonwoven fabric with water or a chemical liquid. This wiping material exhibits a high wet tensile strength, because the rayon fibers are mutually bonded. However, this wiping material is disadvantageous in that the rubber type binder renders the resultant wiping material malodorous. Also, this wiping material is disadvantageous in that the rubber type binder causes the resultant sheet to have a rough texture and an unsatisfactory feel during use thereof.

Accordingly, an attempt was made to intertwine the rayon fibers, and to provide a nonwoven fabric free from the rubber type binder.

It was assumed that the rayon fibers can be intertwined by applying a plurality of water jet streams to a web made by layering the rayon fibers.

Nevertheless, it was found that for the purpose of satisfactorily intertwining the rayon fibers by applying the water jet streams to the web made from the layered rayon fibers, the web must be formed from a large amount of layered rayon fibers. Namely, when made from a small amount of layered rayon fibers, the resultant web has a number of gaps formed between the layered rayon fibers and having a large size, and thus the water jet streams applied to the web can be easily passed through the gaps without striking against the rayon fibers. Therefore, the applied water jet streams cannot effectively impart a high kinetic energy to the rayon fibers and thus, the rayon fibers cannot sufficiently move in relation to each other and intertwine.

For the rayon fibers to sufficiently intertwine, a large amount of rayon fibers must accumulate to render the size of the gaps formed between the rayon fibers small. However, when the web is made from a large amount of accumulated rayon fibers, the resultant wiping fabric is undesirably too thick and the quality thereof is unnecessarily high for a disposable sheet material.

The inventors of the present invention have studied a new technology that allows the rayon fibers or other fibers to satisfactorily intertwine even when the amount of accumulated fibers in the web is small. As a result, the inventors found that in a web formed from the rayon fibers or other layered fibers, the intertwining of the fibers by the application of water jet streams can be effectively enhanced by preventing formation of gaps having a relatively large size. In this attempt, a thin paper sheet is superimposed on a web formed from filaments, for example, layered rayon filaments, and a plurality of water jet streams are applied to the surface of the thin paper sheet placed on the filament web under high pressure. In this procedure, the pulp fibers in the thin paper sheet are fully intertwined with the filaments in the web and the filaments are also fully intertwined through the pulp fibers. Therefore, the resultant nonwoven fabric has satisfactory water-absorbing properties and a high wet tensile strength and thus is useful as a wiping material.

Nevertheless, the above-mentioned procedures for producing the nonwoven fabric was disadvantageous in that, when the high pressure water jet streams are ejected onto the thin paper sheet placed on the filament web, the thin paper sheet is significantly broken by the water jet streams to such an extent that the pulp fibers in the broken thin paper sheet are scattered in the ambient atmosphere. Therefore, the pulp fibers from which the thin paper sheet is formed do not uniformly intertwine with the filaments and the resultant nonwoven sheet is provided with portions thereof, in which pulp fibers are not present and it has an uneven structure and quality.

Also, since a portion of the pulp fibers of the thin paper sheet is dispersed into the ambient atmosphere, the resultant nonwoven sheet has a lowered content of pulp fibers and thus sometimes exhibits a reduced hydrophilic property.

Usually, after the water jet stream application under high pressure is completed, the used water streams are recovered, filtered through a filter material and then returned to the water jet stream application under igh

pressure. Where the thin paper sheet is broken by the high pressure water jet streams and a portion of the pulp fibers of the thin paper sheet is dispersed, the recovered water streams contain the pulp fibers and thus in the filtration step, the filter is blocked by the pulp fibers. Therefore, the nonwoven sheet producing procedures cannot be continuously carried out over a long time. If the pulp fibers contained in the used water streams are discharged without recovering, the resultant waste water pollutes the environment.

## SUMMARY OF THE INVENTION

An object of the present invention is to provide a process for producing a wiping nonwoven fabric in which a plurality of pulp fibers and a plurality of filaments are uniformly intertwined, without causing an undesirable dispersion of the pulp fibers when a plurality of water jet streams are applied under high pressure.

Another object of the present invention is to provide a process for producing a wiping nonwoven fabric by applying a plurality of water jet streams to a laminate of a filament web and a pulp fiber paper sheet, under high pressure, in which method, the water streams are contaminated with pulp fibers in a restricted amount, and thus the process can be continuously carried out over a long period of time.

The above-mentioned objects can be attained by the process of the present invention comprising the steps of:

laminating a paper sheet comprising a plurality of pulp fibers and having a wet tensile strength of 0.04 to 1.5 kg/25 mm width determined by using a specimen having a width of 25 mm in accordance with Japanese Industrial Standard P 8135, on a surface of a filament web in which a plurality of filaments are randomly layered;

applying a plurality of water jet streams toward the paper sheet layer surface of the resultant laminate under a pressure high enough to allow the water jet streams to penetrate into the filament web layer through the paper sheet layer, thereby causing the pulp fibers and the filaments to intertwine so as to form a nonwoven fabric.

In an embodiment of the process of the present invention, the laminate consisting of the paper sheet and the filament web is superimposed on a porous support sheet; the water jet streams are applied toward the paper sheet layer surface under a pressure high enough to allow the water jet streams to penetrate through the laminated paper sheet, the filament web and the porous support sheet; and the resultant nonwoven fabric is removed from the porous support sheet.

In this embodiment, application of the water jet streams causes a plurality of perforations having a cross-sectional area of 0.01 to 4 mm$^2$ to form in the resultant nonwoven fabric. The perforations are distributed preferably at a distribution density of 6 to 600 perforations per cm$^2$ of the surface area of the resultant nonwoven fabric.

In another embodiment of the process of the present invention, the water jet streams impart an energy of 0.1 kWh or more calculated in accordance with the equation (I);

$$E = (Q\rho V^2)/2 \quad \mathrm{I}$$

wherein E represents an energy (work) in kWh imparted by the water jet streams, Q represents the weight of water in kg necessary to convert the laminate having a weight of 1 kg to a nonwoven fabric, V represents a flow velocity in m/sec of the water jet streams and $\rho$ represents a specific gravity of the water used, on the laminate.

In this embodiment, the application causes portions of the pulp fibers to penetrate the filament web and to partially cover a surface of the filament web not brought into contact with the paper sheet, at a total covering area corresponding to 2% or more of the entire surface area of the filament web.

In still another embodiment of the process of the present invention, the filaments in the filament web are fuse bounded to each other at a plurality of bonding regions thereof and spaced from each other; each of the bonding regions having an area of 0.01 to 4 mm$^2$ and the total area of the bonding regions corresponding to 2 to 20% of the entire surface area of the filament web.

In still another embodiment of the process of the present invention, the paper sheet is produced from pulp having a Canadian Standard Freeness of 600 m$\ell$ or more, determined in accordance with the Japanese Industrial Standard P 8121.

## DESCRIPTION OF THE PREFERRED EMBODIMENTS

In the process of the present invention, first, a filament web in which a plurality of filaments are randomly layered so as to form a web. The filaments usable for the present invention can be selected from known filaments, for example, rayon filaments, polyolefine filaments (for example, polyethylene filaments and polypropylene filaments), polyester filaments for example, polyethylene terephthalate filaments, and polyacrylic ester filaments.

The filaments are used for the present invention because when a plurality of filaments are intertwined, the resultant filament web exhibits a higher tensile strength and dimensional stability than those of a short fiber web formed from cut fibers.

Preferably, the filaments usable for the present invention have a thickness of 1 to 4 deniers (10/9 to 40/9 d tex), and when the thickness is more than 4 denier (40/9 d tex), the softness of the resultant filament web is reduced, and thus when the resultant nonwoven fabric is used as a wiping material, the texture thereof is unsatisfactory. Also, if the thickness is less than 1 denier (10/9 d tex), it becomes necessary to strictly control the filament-producing conditions and thus it becomes difficult to produce the filament and the filament web at a high speed. Preferably, the filament web usable for the present invention has a basis weight of 5 to 30 $g/m^2$. If the basis weight is more than 30 $g/m^2$, even when the laminate composed of the filament web and a paper sheet superimposed on the filament web are subjected to a plurality of water jet streams under high pressure, so as to penetrate the paper sheet and the filament web, it becomes difficult for the pulp fibers, from which the paper sheet is formed, to easily move through the surface of the filament web brought into contact with the paper sheet to the opposite surface of the filament web, and thus the pulp fibers are locally distributed in the resultant nonwoven fabric. In this case, the resultant nonwoven fabric has a surface portion thereof, in which the pulp fibers are distributed in a small amount. Thus, this surface portion exhibits a low hydrophilic property.

Also, if the basis weight of the filament web is less than 5 $g/m^2$, the resultant filament web exhibits a reduced dimensional stability and the resultant wiping nonwoven fabric has a poor wet tensile strength. Also, the small basis weight causes the resultant filament web to have large gaps between the layered filaments. Further, there is a risk that when the high pressure water jet streams are applied to the laminate, the pulp fibers flow out of the laminate by the water jet streams through the gaps. Also, the flowed water streams, which are recovered, contain a large amount of pulp fibers.

In the filament web usable for the present invention, the filaments may be fuse-bonded to each other at intersecting points thereof to form a nonwoven filament fabric. Also, the filaments may not be bonded to each other and may form a filament fleece.

Particularly, in the nonwoven filament fabric in which the filaments are fuse bonded to each other, it is preferable that the fuse-bonding points or regions be spaced from each other and evenly distributed throughout the web, because the resultant nonwoven fabric has an enhanced dimensional stability due to the mutual fuse-bonding of the filaments to each other, and since the non-fuse-bonded portions of the filaments are layered without restriction, the pulp fibers are easily intertwined with the filaments and the resultant nonwoven fabric exhibits a satisfactory softness and flexibility.

Secondly, a paper sheet is laminated on a surface of the filament web. In the present invention, it is essential for the paper sheet to have a specific wet tensile strength of 0.04 to 1.5 kg/25 mm width, preferably 0.06 to 1.2 kg/25 mm width, determined in accordance with Japanese Industrial Standard (JIS) P 8135.

If the wet tensile strength is less than 0.04 kg/25 mm, the resultant paper sheet is significantly broken by the high pressure water jet streams before the paper sheet is brought into close contact with the filament web by the high pressure of the water jet streams, or the pulp fibers from which the paper sheet is formed are scattered, and thus it is difficult for the pulp fibers to intertwine with the filaments in the filament web evenly throughout the resultant nonwoven fabric. Also, damage to the paper sheet sometimes makes a continuous supply of the paper sheet onto the filament web difficult or impossible. Also, damage to the paper sheet results in an uneven distribution of pulp fibers and causes wrinkles in the resultant nonwoven fabric. In the wrinkled portions of the nonwoven fabric, the pulp fibers and the filaments are not always satisfactorily intertwined with each other.

If the wet tensile strength is more than 1.5 kg/25 mm, the pulp fibers in the paper sheet exhibit an enhanced resistance to movement even when high pressure water jet streams are applied thereto, and thus it becomes difficult to satisfactorily intertwine with the filaments. Also, if the pulp fibers are unevenly distributed, the resultant nonwoven fabric has an undesirable portion thereof, in which the pulp fibers are locally distributed in one surface portion of the filament web. This nonwoven fabric has an opposite surface portion thereof, in which the pulp fibers are distributed in a small amount. This opposite surface portion exhibits a lowered hydrophilic property.

The wet tensile strength of the paper sheet can be adjusted to a desired level by conventional methods. For example, in the production of the paper sheet, a wet paper strength agent, for example, polyamidoepichlorohydrin or melamine resin, may be applied to the paper sheet.

The basis weight of the paper sheet usable for the present invention is not restricted to a specific level. The paper sheet, however, preferably has a basis weight of from 10 to 100 $g/m^2$ determined in accordance with the Japanese Industrial Standard (JIS) P 8124. If the basis weight is less than 10 $g/m^2$, the resultant nonwoven fabric has a small content of pulp fibers and thus the resultant wiping fabric sometime exhibits unsat-

isfactory water-absorption and water-retention.

Also, if the basis weight is more than 100 g/m², the resultant laminate has an excessive amount of pulp fibers, and thus it is sometimes difficult for the high pressure water jet streams to impart a sufficient amount of kinetic energy to the pulp fibers, thereby causing the pulp fibers and the filaments to sufficiently intertwine. Also, an excessive amount of pulp fibers sometimes results in the lowering of the softness of the resultant wiping nonwoven fabric.

The pulp fibers usable for forming the paper sheet are preferably selected from bleached and unbleached pulp fibers prepared by pulping hard and/or soft wood materials in accordance with any one of the kraft method, sulfite method, soda method and polysulfide method; mechanical pulp fibers, for example, ground pulp fibers and thermo-mechanical pulp fibers; and mixtures of the above-mentioned pulp fibers.

The soft wood pulp fibers and the hard wood pulp fibers are preferably employed in a mixing ratio of 100/0 to 20/80, more preferably 100/0 to 40/60. If the hard wood pulp fibers are employed in a proportion of more than 80%, the loss of pulp fibers due to the application of the high pressure water jet streams increases, and also, the resultant nonwoven fabric has a lowered degree of softness.

Preferably, the paper sheet usable for the present invention has an apparent density of 0.6 g/cm³ or less, more preferably 0.55 g/cm³ or less, determined in accordance with JIS P 8118. If the density is more than 0.6 g/cm³, the movement of the pulp fibers due to the application of the high pressure water jet streams is sometimes restricted and the amount of energy necessary for the pulp fibers and the filaments to intertwine with each other increases undesirably.

In the process of the present invention, the paper sheet is laminated on a surface of the filament web prepared as mentioned above. In this lamination, the filament web and the paper sheet are preferably employed in a basis weight ratio of 1/1 to 1/19. If the basis weight ratio is more than 1/1, the amount of pulp fibers in comparison with that of the filaments is too small and thus the resultant wiping nonwoven fabric sometimes exhibits unsatisfactory water-absorption and water-retention . Also, since the proportion of the filaments, which are relatively expensive, to the pulp fibers, which are inexpensive becomes excessive, the resultant wiping nonwoven fabric is expensive. Also, if the basis weight ratio is less than 1/19, it becomes difficult for all of the pulp fibers in the laminate to intertwine with the filaments, and thus when the resultant wiping nonwoven fabric is used under wet conditions, the non-intertwined portion of the pulp fibers easily fall from the fabric.

After the paper sheet is laminated on the filament web, a plurality of water jet streams are applied under high pressure toward the paper sheet layer surface of the laminate so as to allow the water jet streams to penetrate the filament web layer through the paper sheet layer. The water jet streams can be formed by applying water through a plurality of small nozzle holes under high pressure. Preferably the nozzle holes have a hole diameter of 0.01 to 0.3 mm. Also, the pressure applied to the water jet streams is preferably 10 to 150 kg/cm².

When the high pressure water jet streams flow through the nozzle holes, the spouted water jet streams strike the Surface of the paper sheet and cause the paper sheet to be brought into close contact with the filament web. The water jet streams then break the paper sheet so as to be in close contact with the filament web, thereby causing the individual pulp fibers to be released from each other. Also, the water jet streams randomly deform, for example, bend and/or twist, the pulp fibers, while imparting kinetic energy to the pulp fibers, thereby enabling the pulp fibers to move randomly.

The above-mentioned complicated movements of the pulp fibers derived from the application of the high pressure water jet streams cause the pulp fibers to penetrate the filament web and intertwine with the filaments in the web and also cause the filaments in the web to intertwine with each other through the pulp fibers.

In the resultant wiping nonwoven fabric, the pulp fibers and filaments are intertwined so as to form a fibrous sheet. The wiping nonwoven fabric of the present invention is impregnated with a desired additive, for example, a wetting agent, for example water and propylene glycol; an antifungus agent, for example, ethyl alcohol and p-hydroxybenzoic acid; a mildewproofing agent, and an aromatic, if necessary.

The nonwoven fabric of the present invention is useful as a disposal towel, napkin, wet tissue sheet, wiper and dustcloth.

In an embodiment of the process of the present invention, the laminate formed from the paper sheet and the filament web is placed on a porous support sheet; the water jet streams are applied toward the paper sheet layer surface under a pressure sufficient to allow the water jet streams to penetrate the laminated paper sheet, filament web and porous support sheet; and the resultant nonwoven fabric is removed from the porous support sheet. In this case, the water jet streams are preferably applied under a pressure of 10 to 150 kg/cm², and the pulp fibers penetrate the filament web and are intertwined with the filaments. Also, the filaments intertwine through the pulp fibers.

In this embodiment, since the laminate consisting of the filament web and the paper sheet superimposed on the filament web is placed on a porous support sheet, and the water jet streams are applied under such a high pressure that the water streams can pass through the laminated paper sheet, filament web and porous

support sheet, the resultant nonwoven fabric has a plurality of perforations (throughholes) formed therethrough. The cross-sectional area and the number of perforations are variable, to a certain extent, depending on the type of porous supporting sheet.

The porous supporting sheet preferably comprises at least one woven fabric made from a plurality of fine filament yarns. The fine filament yarns are preferably selected from the group consisting of stainless steel filament yarns, bronze filament yarns and plastic filament yarns. Preferably, the fine filament yarns have an average thickness of 0.2 to 1.5 mm. The plastic filament yarns can be selected from polyester filament yarns, polyfluoro-ethylene filament yarns and polyamide filament yarns.

Although there is no restriction on the weaving structure of the woven fabric for the porous supporting sheet, it is preferable that a plain weave, a satin weave, a double layer weave, a twill weave and the like be utilized. Also, the woven fabric preferably has a warp and weft density of 3 to 36 yarns/cm.

As mentioned above, the perforations are preferably formed by the high pressure water jet streams. Nevertheless, the perforations may be formed after the nonwoven fabric is formed by using or not using the porous supporting sheet. The formation of the perforations can be effected by needling or punching.

The perforations formed in the nonwoven fabric preferably have a cross-sectional area of 0.01 to 4 mm$^2$, more preferably 0.02 to 4 mm$^2$. If the cross-sectional area of the perforations is less than 0.01 mm$^2$, when the nonwoven fabric is rinsed with water after being employed, for example, for wiping, it becomes difficult for the rinsing water to easily pass through the perforations in the direction of the thickness of the fabric and thus to remove dust caught in the perforations by the rinsing water flowing through the perforations. If the cross-sectional area is more than 4 mm$^2$, it is difficult for the resultant perforations to catch dust therein due to the excessive size thereof. Also, it is difficult for the large perforations to retain water therein and thus the resultant nonwoven fabric sometimes exhibits lowered water-absorption and water-retention.

Preferably, the perforations are distributed in the resultant nonwoven fabric at a distribution density of 6 to 600 perforations/cm$^2$, preferably 9 to 300 perforations/cm$^2$.

If the distribution density is less than 6 perforations/cm$^2$, this small number of perforations causes in a water-rinsing operation for the nonwoven fabric, the amount of water flowing therethrough in the direction of the thickness of the nonwoven to be small and thus it becomes difficult to remove dust caught in the edge portions of the perforations and gaps between the fibers and filaments, with a high degree of efficiency. Also, the small number of perforations results in a reduction in the dust-catching effect by the edge portions of the perforations and gives the resultant nonwoven fabric having an unsatisfactory texture.

Practically, it is difficult to form the perforations at a high distribution density of more than 600 perforations/cm$^2$, and it is difficult to form perforations having a cross-sectional area of 0.01 mm$^2$ or more, at a high distribution density thereof.

The perforations may be formed in the nonwoven fabric in accordance with a certain pattern or randomly. When the perforations are distributed in accordance with a certain pattern, the resultant nonwoven fabric has a preferable gauze-like appearance, texture and softness.

In another embodiment of the process of the present invention, the laminate consisting of the filament web and the paper sheet laminated on the filament web is imparted with a high pressure water jet stream energy (work) of 0.1 kWh or more, preferably 0.15 kWh or more, calculated in accordance with the equation (I)

$$E = (Q\rho V^2)/2 \quad (I)$$

wherein E represents an energy (work) in kWh imparted by the water jet streams to the laminate, Q represents a weight of water in kg necessary to convert the laminate having a weight of 1 kg to a nonwoven fabric, V represents a flow velocity in m/sec of the water jet streams, and ρ represents a specific gravity of the water used.

When the energy as mentioned above is applied to the laminate, the water jet streams penetrate the paper sheet layer and the filament layer and cause a portion of the pulp fibers to penetrate the filament web and partially cover a back surface of the filament web, with which the paper sheet is brought into contact, at a total covering area corresponding to 2% or more, preferably 4% or more, of the entire surface area of the filament web surface.

When the imparted energy is less than 0.1 kWh, the striking strength of the water jet streams on the laminate is not high enough to cause the portion of the pulp fibers to extend from the back surface of the filament web at the above-mentioned covering area of 2% or more.

The covering area of the pulp fibers on the back filament web surface can be determined by the following method.

The back filament web surface of the resultant nonwoven fabric is photographed by an optical microscope at a magnification of 20, the resultant photograph is subjected to an image-analyzing apparatus to measure a total area of the portions of the filament web surface covered by the pulp fibers appearing on the surface. A percent covering area is calculated in accordance with the following equation: Percent covering area (%) = (Total area of the covered portions)/(Entire area of the back surface of filament web) x 100.

In the above-mentioned test method, the filament web back surface is photographed at 20 portions thereof, with each having an area of 0.25 $cm^2$. The percent covering area is calculated by averaging the resultant data.

If the percent covering area is less than 2%, the amount of pulp fibers located in the back surface portion of the resultant nonwoven fiber is sometimes too small, and thus the resultant nonwoven fabric exhibits, at the back surface thereof, unsatisfactory water-absorption and water-retention. When the percent covering area is 2% or more, the resultant nonwoven fabric exhibits satisfactory water-absorption and water-retention, even at the back surface thereof.

In still another embodiment of the process of the present invention, the accumulated filaments in the filament web are fuse-bonded with each other at a plurality of bonding regions thereof, spaced from each other. Preferably, each bonding region preferably has an area of 0.01 to 4 $mm^2$, more preferably 0.04 to 2 $mm^2$, and a total area of the bonding regions corresponds to 2 to 20%, more preferably 4 to 15%, of the entire surface area of the filament web.

In this embodiment, the filament web has a plurality of filament-bonded portions spaced from each other and filament-nonbonded portions. The filament bonded portions cause the filament web to exhibit an enhanced dimensional stability and an improved mechanical strength.

In the filament-nonbonded portions, the filaments have a high freedom of relative movement thereof. Thus, the filament-nonbonded portions have a relatively high degree of softness.

When the high pressure water jet streams are applied, the filaments in the filament-nonbonded portions move easily to form relatively large gaps between the filaments, and the pulp fibers can move through the gaps. The size of the gaps can be controlled by controlling the distribution density and the size of the filament-bonding regions.

When the area of the each filament-bonding region is less than 0.01 $mm^2$, the gaps formed between the filaments, by the application of the high pressure water jet streams, become too large and the amount of pulp fibers undesirably flowing through the gaps is excessive. Also, the resultant nonwoven fabric sometimes exhibits an unsatisfactory mechanical strength and therefore, when a wiping fabric made from the nonwoven fabric is used under a high friction conditions, the sheet sometimes tears.

If the area of each filament-bonding region is more than 4 $mm^2$, it is difficult for the pulp fibers to intertwine with the filaments and thus a large amount of pulp fibers flows off from the filament web. Also, the large filament-bonding regions cause the filament web to exhibit a lowered softness, and the resultant non-woven fabric to have a low degree of softness and a poor texture.

When the total area of the filament-bonding regions is less than 2%, the applied high pressure water jet streams form large gaps between the filaments and thus the amount of pulp fibers flowing off through the gaps is increased. Also, the filament web has a relatively low tensile strength and sometimes, the resultant nonwoven fabric exhibits an unsatisfactory resistance to frictional damage thereof.

Also, when the total area of the filament-bonding regions is more than 20%, the movement of the filaments is restricted to an excessive extent and thus the filaments cannot intertwine with the pulp fibers. Also, since the filament web is not soft, the resultant nonwoven fabric has a lowered softness and a poor texture.

A filament web having a plurality of bonding regions can be produced by the following method.

Namely, a filament web in which a plurality of filaments accumulate in layers is continuously pressed between a roughening roll and a smooth roll at a high temperature. In this press, the filament web is locally pressed and the pressed portions of the filaments are fuse-bonded or soft-bounded to each other by the protruding portions of the roughening roll. The smooth roll can be replaced by a roughening roll. In this case, the bonding regions are formed by the protruding portions of the upper and lower roughening rolls.

In a further embodiment of the process of the present invention, the paper sheet is produced from a pulp having a Canadian Standard Freeness of 600 ml or more, determined in accordance with Japanese Industrial Standard (JIS) P8121, by a wet paper-forming method.

The Canadian Standard Freeness is mutually relative to the degree of beating (refining). The higher the Canadian Standard Freeness, the lower the degree of beating.

If a pulp having a Canadian Standard Freeness of less than 600 $m\ell$ is used to produce a paper sheet, the pulp fibers in the resultant paper sheet exhibit a high resistance to the release of individual pulp fibers from each other when high pressure water jet streams are applied to the paper sheet. This high resistance to mutual release of the pulp fibers causes insufficient intertwining of the filaments with the pulp fibers. Also, the resultant nonwoven fabric exhibits a relatively high degree of stiffness.

When the pulp fibers are not fully separated from each other, the applied water is retained on the surface of the paper sheet, and thus cannot permeate the laminate. The retained water is struck with the following water jet streams and scattered to the ambient atmosphere. Therefore, the resultant nonwoven fabric has a high concentration of a plurality of water drops containing pulp fibers that adhere to the surface of the fabric.

The adhered pulp fibers render the surface of the resultant dry nonwoven fabric unevenly rough.

In the pulp having a Canadian Standard Freeness of less than 600, and a high degree of beating, the pulp fibers are fibrillized and twisted at a high intensity and thus can be closely intertwined. The paper sheet made from the above-mentioned highly beaten pulp fibers has a high resistance to wet damage and the pulp fibers in the paper sheet are not easily separated from each other, even when the water jet streams are applied thereto under high pressure.

In the process of the present invention, the paper sheet may be produced from a non-beaten pulp. In the non-beaten pulp, the pulp fibers have a low degree of fibrillation and twisting. When the high pressure water jet streams are applied to the non-beaten pulp paper sheet, the pulp fibers can be easily separated from each other, penetrate the filament web and intertwine with the filaments.

A typical bleached soft wood kraft pulp has a Canadian Standard Freeness of about 730 mℓ and a typical bleached hard wood kraft pulp has a Canadian Standard Freeness of about 650 ml.

## EXAMPLES

The present invention will be further illustrated by way of the following working examples.

In the examples, the resultant products were subjected to the following tests.

### 1) Water absorption

This property was evaluated by an organoleptic test. The evaluation results were indicated in accordance with the following five classes.

| Class | Result |
|---|---|
| 5 | Very high water absorption rate |
| 4 | High water absorption rate |
| 3 | Moderate water absorption rate |
| 2 | Low water absorption rate |
| 3 | Very low water absorption rate |

### 2) Water retention

A test fabric piece was immersed in water at room temperature for 30 seconds, and then removed from the water. The wet test piece was interposed between a pair of filter paper sheets having a basis weight of 250 g/m² and pressed under a load of 5 g/m² for 30 seconds. The water retention of the tested piece was calculated in accordance with the equation:

$$\text{Water retention (\%)} = \frac{W_1 - W_0}{W_0} \times 100$$

wherein $W_0$ represents of the original weight of the test piece before the test treatment, and $W_1$ represents of the weight of the test piece after the test treatment.

### 3) Wiping performance

A test piece was immersed in water at room temperature for 30 seconds and lightly squeezed.

A desk surface was lightly wiped with the wet test piece. The wiping performance and resistance to breakage of the wet test pieces were evaluated organoleptically and the evaluation results were indicated in accordance with the following five classes.

| Class | Result |
|---|---|
| 5 | Wiping performance is excellent and a reduction in mechanical strength is substantially not apparent. |
| 4 | Wiping performance is good and there is a slight reduction in mechanical strength. |
| 3 | Wiping performance is satisfactory and there is a moderate reduction in mechanical strength. |
| 2 | Wiping performance is poor and there is a large reduction in mechanical strength. |
| 1 | Wiping performance is very poor and there is a very large reduction in mechanical strength. |

(4) Touch

The tactile quality (when touched) of the test piece was organoleptically evaluated in accordance with the following five classes.

| Class | Result |
|---|---|
| 5 | Very smooth good tactile quality |
| 4 | Smooth good tactile quality |
| 3 | Moderate satisfactory tactile quality |
| 2 | Slightly poor tactile quality |
| 1 | Very poor tactile quality |

(5) Repeated useability

A test piece was immersed in water at room temperature for 30 seconds lightly squeezed, and crumpled by hand. The above-mentioned operations were repeated 10 times or more. The capability of the test piece for repeated use was evaluated organoleptically, and the evaluation results were indicated in accordance with the following five classes.

| Class | Result |
|---|---|
| 5 | Substantially no reduction in mechanical strength occurs and repeated useability is excellent. |
| 4 | Slight reduction in mechanical strength occurs and repeated useability is high. |
| 3 | Small reduction in mechanical strength occurs and repeated useability is satisfactory. |
| 2 | Large reduction in mechanical strength occurs and repeated useability is poor. |
| 1 | Significant reduction in mechanical strength occurs and repeated usability is very poor. |

(6) Surface evenness

The degree of surface evenness of a test piece was evaluated organoleptically and indicated in accordance with the following five classes.

| Class | Result |
|---|---|
| 5 | Excellent |
| 4 | Good |
| 3 | Satisfactory but partially slightly uneven |
| 2 | Partially uneven |
| 1 | Entirely uneven |

(7) Softness

The degree of softness of the test piece was evaluated by an organoleptic examination in accordance with the following five classes.

| Class | Result |
|---|---|
| 5 | Excellent |
| 4 | Good |
| 3 | Moderate |
| 2 | Slightly stiff |
| 1 | Stiff |

Example 1

A filament web was prepared by randomly accumulating a plurality of polypropylene filaments and locally fuse-bonding the accumulated filaments with each other at a plurality of fuse-bonding regions randomly located in the web. The polypropylene filaments had an individual filament thickness of 2.5 denier (2.5 x 10/9 d tex), and the filament web had a basis weight of 20 g/m$^2$.

A paper sheet was produced from bleached soft wood kraft pulp fibers by a wet paper-forming method. This paper sheet had a wet tensile strength of 0.1 kg/25 mm width determined by using a specimen with a width of 25 mm in accordance with JIS P8135, a basis weight of 30 g/m$^2$, and an apparent density of 0.35 g/cm$^3$.

The paper sheet was laminated on a surface of the filament web.

The laminate was placed on a conveyor belt made from a metal wire net in such a condition that the paper sheet is located on the filament web.

A plurality of high pressure water jet streams formed by spouting water through a jet nozzle having a plurality of jetting holes having an inside diameter of 0.1 mm and arranged at intervals of 1 mm under a pressure of 30 kg/cm$^2$ were applied to the paper sheet layer surface of the laminate, while moving the laminate on the conveyor belt at a speed of 30 m/min.

The pulp fibers of the paper sheet penetrate the filament web and intertwine with the filaments to form a nonwoven fabric that is useful as a wiping material.

The test results are shown in Table 1.

Example 2

A filament web was prepared by randomly accumulating a plurality of polyethylene terephthalate filaments and locally fuse-bonding the polyethylene terephthalate filaments with each other at a plurality of fuse-bonding regions randomly located in the web. The filaments in the filament web had a thickness of 2.3 denier (2.3 x 10/9 d tex) and the filament web had a basis weight of 20 g/m$^2$.

A paper sheet was produced from a mixture of 80% by weight of bleached soft wood kraft pulp fibers and 20% by weight of bleached hard wood kraft pulp fibers by a wet paper-forming method.

This paper sheet had a wet tensile strength of 0.3 kg/25 mm width, measured in accordance with JIS

P8135, a basis weight of 80 g/m$^2$ and an apparent density of 0.54 g/cm$^2$, measured in accordance with JIS P8118.

The paper sheet was laminated on a surface of the filament web to form a laminate.

The laminate was placed on a conveyor belt made from a metal wire net in such a condition that the paper sheet was located on the filament web.

A plurality of high pressure water jet streams formed by spouting water through a jet nozzle having a plurality of jetting holes with an inside diameter of 0.1 mm and arranged at intervals of 1 mm under a pressure of 60 kg/cm$^2$, were applied to the paper sheet layer surface of the laminate, while moving the laminate on the conveyor belt at a speed of 30 m/min.

The pulp fibers of the paper sheets penetrated the filament web and intertwined with the filaments to form a nonwoven fabric useful as a wiping material.

The test results are shown in Table 1.

Example 3

A filament web was prepared by randomly accumulating a plurality of polypropylene filaments and locally fuse-bonding the polypropylene filaments with each other at a plurality of fuse-bonding regions randomly located in the web. The filaments in the filament web had a thickness of 2.0 denier (2.0 x 10/9 d tex) and the filament web had a basis weight of 10 g/m$^2$.

A paper towel was produced using a wet paper-forming method.

This paper towel had a wet tensile strength of 0.1 kg/25 mm width, measured in accordance with JIS P 8135, a basis weight of 22 g/m$^2$ and an apparent density of 0.28 g/cm$^2$, measured in accordance with JIS P8118.

The paper sheet was laminated on a surface of the filament web to form a laminate.

The laminate was placed on a conveyor belt made from a metal wire net in such a condition that the paper sheet was located above the filament web.

A plurality of high pressure water jet streams formed by spouting water through a jet nozzle having a plurality of jetting holes with an inside diameter of 0.15 mm and arranged at intervals of 1 mm under a pressure of 30 kg/cm$^2$, were applied to the paper towel layer surface of the laminate, while moving the laminate on the conveyor belt at a speed of 30 m/min.

The pulp fibers of the paper towel penetrated the filament web and intertwined with the filaments to form a nonwoven fabric useful as a wiping material.

The test results are shown in Table 1.

Comparative Example 1

The same procedures as in Example 1 were carried out except that the paper sheet had a wet tensile strength of 0.03 kg/25 mm width. During the application of the high pressure water jet streams, the paper sheet was often significantly damaged and the pulp fibers were scattered. Due to the damage to the paper sheet, the nonwoven fabric-forming procedure was often stopped.

The test results are shown in Table 1.

Comparative Example 2

The same procedures as in Comparative Example 1 were carried out except that the basis weight of the paper sheet was changed to 20 g/m$^2$ and the water jet streams were applied under a pressure of 40 kg/cm$^2$.

During the application of the water jet streams, the paper sheet was often significantly damaged and pulp fibers were scattered. Due to the damage to the paper sheet, the nonwoven fabric-forming procedure was often stopped.

The test results are shown in Table 1.

Comparative Example 3

The same filament web as in Example 1 was subjected, as a wiping fabric to the above-mentioned tests.

The test results are shown in Table 1.

Comparative Example 4

The same paper sheet as in Example 1 was subjected to the above-mentioned tests.

The test results are shown in Table 1.

Table 1

| Example No. | Item | Water absorption (class) | Water retention (%) | Wiping performance (class) | Touch (class) | Repeated useability (class) | Surface evenness (class) |
|---|---|---|---|---|---|---|---|
| Example | 1 | 5 | 100 | 5 | 5 | 5 | 5 |
| | 2 | 5 | 140 | 5 | 5 | 5 | 5 |
| | 3 | 5 | 120 | 5 | 5 | 5 | 5 |
| Comparative Example | 1 | 2 | 40 | 3 | 2 | 4 | 2 |
| | 2 | 2 | 20 | 2 | 2 | 4 | 2 |
| | 3 | 1 | 0 | 1 | 2 | 5 | 5 |
| | 4 | 5 | 140 | 4 | 2 | 1 | 5 |

Table 1 clearly shows that the wiping nonwoven fabrics of Examples 1 to 3 made in accordance with the present invention exhibited excellent water absorption, water retention, wiping performance, tactile quality, repeated useability and surface evenness.

In Comparative Examples 1 and 2, the paper sheet having a low wet tensile strength was damaged by the application of the high pressure water jet streams, and a portion of the pulp fibers was scattered. Therefore,

the amount of the remaining pulp fibers, which were intertwined with the filaments, was smaller than that of Examples 1 to 3. Accordingly, the nonwoven fabrics of Comparative Examples 1 and 2 exhibited low water absorption, poor water retention, poorer wiping performance than that of Examples 1 to 3, low tactile quality and a low surface evenness.

In Comparative Example 3, the filament web exhibited very good hydrophobic properties and thus poor water absorption, water retention and wiping performance.

In Comparative Example 4, the paper sheet exhibited poor tactile quality, repeated useability. Also, the wiping performance of the paper sheet in Comparative Example 4 was lower than that in Example 1.

## Example 4

A filament web was prepared by randomly accumulating a plurality of polypropylene filaments and locally fuse-bonding the accumulated filaments with each other at a plurality of fuse-bonding regions randomly located in the web. The filament web had a basis weight of 15 g/m² and the filaments had a thickness of 2.5 denier (2.5 x 10/9 d tex). On the surface of the filament web, a paper sheet free from fibers other than pulp fibers was laminated. This paper sheet had a wet tensile strength of 0.1 kg/25 mm, a basis weight of 30 g/m² measured in accordance with JIS P 8124, and an apparent density of 0.28 g/cm³ measured in accordance with JIS P 8118. This paper sheet was produced from bleached soft wood kraft pulp by a wet paper-forming method. The laminate was placed on a conveyor belt, in such a condition that the filament web layer came into contact with the conveyor belt and the upper surface of the paper sheet layer is exposed above. The conveyor belt was made by weaving stainless steel filament yarns in a plain weave structure in warp and weft densities of 16 yarns/cm.

A plurality of water jet streams were spouted through a jet nozzle having a plurality of jetting holes with an inside diameter of 0.1 mm arranged in a distribution density of 16 holes/cm in the longitudinal and transversal directions thereof, under a pressure of 50 kg/cm², toward the upper surface of the paper sheet, while moving the conveyor belt at a speed of 30 m/min. The water jet streams passed through the laminate and the conveyor belt and were discharged through the lower surface of the conveyor belt. By the above-mentioned application of the high pressure water jet streams, the pulp fibers of the paper sheet were intertwined with the filaments of the filament web, to form a nonwoven fabric.

The resultant nonwoven fabric had a plurality of perforations (throughholes) having an oval cross-sectional profile with a cross-sectional area of 0.1 to 0.2 mm² and a plurality of perforations having an oval cross-sectional profile with a cross-sectional area of 0.02 to 0.1 mm², which are alternately distributed at a distribution density of 8 holes/cm in the longitudinal and transversal directions of the nonwoven fabric. Accordingly, the nonwoven fabric had perforations in a distribution density of 16 holes/cm in the longitudinal and transversal directions; namely, 256 holes/cm², and exhibited a beautiful gauze-like appearance.

The test results are shown in Table 2.

## Example 5

A filament web was prepared by randomly accumulating a plurality of polypropylene filaments and locally fuse-bonding the accumulated filaments with each other at a plurality of fuse-bonding regions randomly located in the web. The filament web had a basis weight of 20 g/m² and the filaments had a thickness of 1.5 denier (1.5 x 10/9 d tex). On the surface of filament web, a paper sheet free from fibers other than pulp fibers was laminated. This paper sheet had a wet tensile strength of 1.2 kg/25 mm, a basis weight of 80 g/m² measured in accordance with JIS P 8124, and an apparent density of 0.50 g/cm³ measured in accordance with JIS P 8118. This paper sheet was produced from bleached soft wood kraft pulp by a wet paper-forming method. The laminate was placed on a conveyor belt in such a condition that the filament web layer came into contact with the conveyor belt and the upper surface of the paper sheet layer is exposed above.

The conveyor belt was the same as in Example 4.

The laminate was subjected to the same nonwoven fabric-forming step as in Example 4, except that the pressure was 100 kg/cm².

By this nonwoven fabric-forming step, the pulp fibers of the paper sheet were intertwined with the filaments of the filament web, to form a nonwoven fabric.

The resultant nonwoven fabric had a plurality of perforations (throughholes) having an oval cross-sectional profile with a cross sectional area of 0.05 to 0.3 mm² and a plurality of perforations having an oval cross-sectional profile with a cross-sectional area of 0.02 to 0.2 mm², which are alternately distributed at a distribution density of 8 holes/cm in the longitudinal and transversal directions of the nonwoven fabric. Accordingly, the nonwoven fabric had perforations in a distribution density of 16 holes/cm in the longitudinal and transversal

directions; namely, 256 holes/cm$^2$, and exhibited a beautiful gauze-like appearance.

The test results are shown in Table 2.

Example 6

A filament web was prepared by randomly accumulating a plurality of polyethylene terephthalate filaments and locally fuse-bonding the accumulated filaments with each other at a plurality of fuse-bonding regions randomly located in the web. The filament web had a basis weight of 20 g/m$^2$ and the filaments had a thickness of 2.3 denier (2.3 x 10/9 d tex). On the surface of filament web, a paper sheet free from fibers other than pulp fibers was laminated. This paper sheet had a wet tensile strength of 0.18 kg/25 mm, a basis weight of 30 g/m$^2$ measured in accordance with JIS P 8124, and an apparent density of 0.42 g/cm$^3$ measured in accordance with JIS P 8118. This paper sheet was produced from bleached soft wood kraft pulp by a wet paper-forming method. The laminate was placed on a conveyor belt in such a condition that the filament web layer came into contact with the conveyor belt and the upper surface of the paper sheet layer is exposed above. The conveyor belt is made by weaving stainless steel filament yarns in a plain weave structure in warp and weft densities of 8 yarns/cm.

A plurality of water jet streams were spouted through a jet nozzle having a plurality of jetting holes with an inside diameter of 0.15 mm arranged at intervals of 1 mm in the longitudinal and transversal directions thereof, under a pressure of 80 kg/cm$^2$, toward the upper surface of the paper sheet, while moving the conveyor belt at a speed of 30 m/min. The water jet streams passed through the laminate and the conveyor belt and were discharged through the lower surface of the conveyor belt.

By the above-mentioned application of the high pressure water jet streams, the pulp fibers of the paper sheet were intertwined with the filaments of the filament web, to form a nonwoven fabric.

The resultant nonwoven fabric had a plurality of perforations (throughholes) having an oval cross-sectional profile with a cross-sectional area of 0.1 to 2 mm$^2$, at a distribution density of 64 holes/cm$^2$. The resultant nonwoven fabric exhibited a beautiful gauze-like appearance.

The test results are shown in Table 2.

Example 7

A filament web was prepared by randomly accumulating a plurality of polypropylene filaments and locally fuse-bonding the accumulated filaments with each other at a plurality of fuse-bonding regions randomly located in the web. The filament web had a basis weight of 20 g/m$^2$ and the filaments had a thickness of 3.3 denier (3.3 x 10/9 d tex). On the surface of filament web, a paper sheet free from fibers other than pulp fibers was laminated. This paper sheet had a wet tensile strength of 0.25 kg/25 mm, a basis weight of 35 g/m$^2$ measured in accordance with JIS P 8124, and an apparent density of 0.36 g/cm$^3$ measured in accordance with JIS P 8118. This paper sheet was produced from a blend of 90% by weight of bleached soft wood kraft pulp with 10% by weight of bleached hard wood kraft pulp by a wet paper-forming method. The laminate was placed on a conveyor belt in such a condition that the filament web layer came into contact with the conveyor belt and the upper surface of the paper sheet layer is exposed above. The conveyor belt is made by weaving stainless steel filament yarns in a plain weave structure in warp and weft densities of 4 yarns/cm.

A plurality of water jet streams were spouted through a jet nozzle having a plurality of jetting holes with an inside diameter of 0.15 mm arranged in a distribution density of 10 holes/cm in the longitudinal and transversal directions thereof, under a pressure of 80 kg/cm$^2$, toward the upper surface of the paper sheet, while moving the conveyor belt at a speed of 30 m/min. The water jet streams passed through the laminate and the conveyor belt and were discharged through the lower surface of the conveyor belt.

By the above-mentioned application of the high pressure water jet streams, the pulp fibers of the paper sheet were intertwined with the filaments of the filament web, to form a nonwoven fabric.

The resultant nonwoven fabric had a plurality of perforations (throughholes) having an oval cross-sectional profile with a cross-sectional area of 0.05 to 3 mm$^2$ at a distribution density of 16 holes/cm$^2$. The resultant nonwoven fabric exhibited a beautiful gauze-like appearance.

The test results are shown in Table 2.

Example 8

A filament web was prepared by randomly accumulating a plurality of polyprophylene filaments and locally fuse-bonding the accumulated filaments with each other at a plurality of fuse-bonding regions randomly located in the web. The filament web had a basis weight of 12 g/m$^2$ and the filaments had a thickness of 2.5

denier (2.5 x 10/9 d tex). On the surface of filament web, a paper towel free from fibers other than pulp fibers was laminated. This paper towel had a wet tensile strength of 0.1 kg/25 mm, a basis weight of 22 g/m$^2$ measured in accordance with JIS P 8124, and an apparent density of 0.28 g/cm$^3$ measured in accordance with JIS P 8118. This paper towel was produced from a blend of 60% by weight of bleached soft wood kraft pulp with 40% by weight of bleached hard wood kraft pulp by a wet paper-forming method, and had a fine crape-like pattern. The laminate was placed on a conveyor belt in such a condition that the filament web layer came into contact with the conveyor belt and the upper surface of the paper towel layer is exposed above. The conveyor belt is made by weaving stainless steel filament yarns in a plain weave structure in warp and weft densities of 11 yarns/cm.

A plurality of water jet streams were spouted through a jet nozzle having a plurality of jetting holes with an inside diameter of 0.1 mm arranged in a distribution density of 16 holes/cm in the longitudinal and transversal directions thereof, under a pressure of 40 kg/cm$^2$, toward the upper surface of the paper sheet, while moving the conveyor belt at a speed of 30 m/min. The water jet streams passed through the laminate and the conveyor belt and were discharged through the lower surface of the conveyor belt.

By the above-mentioned application of the high pressure water jet streams, the pulp fibers of the paper sheet were intertwined with the filaments of the filament web, to form a nonwoven fabric.

The resultant nonwoven fabric had a plurality of perforations (throughholes) having an oval cross-sectional profile with a cross-sectional area of 0.02 to 0.8 mm$^2$ arranged in a distribution density of 121 holes/cm$^2$ and exhibited a beautiful gauze-like appearance.

The test results are shown in Table 2.

## Comparative Example 5

The same paper sheet and polypropylene filament web as in Example 1 were laminated and the resultant laminate was placed on a conveyor belt in such a condition that the filament web layer came into contact with the conveyor belt and the upper surface of the paper sheet layer is exposed above. The conveyor belt is made by weaving stainless steel filament yarns in a plain weave structure in warp and weft densities of 40 yarns/cm.

A plurality of water jet streams were spouted through a jet nozzle having a plurality of jetting holes with an inside diameter of 0.1 mm arranged at intervals of 0.4 mm in the longitudinal and transversal directions thereof, under a pressure of 60 kg/cm$^2$, toward the upper surface of the paper sheet, while moving the conveyor belt at a speed of 30 m/min. The water jet streams passed through the laminate and the conveyor belt and were discharged through the lower surface of the conveyor belt.

By the above-mentioned application of the high pressure water jet streams, the pulp fibers of the paper sheet were intertwined with the filaments of the filament web, to form a nonwoven fabric.

The resultant nonwoven fabric had a smooth surface and was substantially not provided with perforations (throughholes) having a cross sectional area of 0.01 mm$^2$ or more.

The nonwoven fabric did not have a gauze-like appearance, and had a lower degree of softness than that in Example 4.

The test results are shown in Table 2.

## Comparative Example 6

The same filament web and paper sheet as in Example 4 were laminated. The resultant laminate was placed on a conveyor belt in such a condition that the filament web layer came into contact with the conveyor belt and the upper surface of the paper sheet layer is exposed above. The conveyor belt is one made by weaving stainless steel filament yarns in a plain weave structure in warp and weft densities of 2 yarns/cm.

A plurality of water jet streams were spouted through a jet nozzle having a plurality of jetting holes with an inside diameter of 0.2 mm arranged at intervals of 1 mm in the longitudinal and transversal directions thereof, under a pressure of 60 kg/cm$^2$, toward the upper surface of the paper sheet, while moving the conveyor belt at a speed of 30 m/min. The water jet streams passed through the laminate and the conveyor belt and were discharged through the lower surface of the conveyor belt.

By the above-mentioned application of the high pressure water jet streams, the pulp fibers of the paper sheet were intertwined with the filaments of the filament web, to form a nonwoven fabric.

The resultant nonwoven fabric had a plurality of perforations (throughholes) having a cross-sectional area of about 6 mm$^2$ in a distribution density of 4 holes/cm$^2$.

The nonwoven fabric exhibited a poor tactile quality and did not have a gauze-like appearance.

The test results are shown in Table 2.

Comparative Example 7

A filament web was prepared by randomly accumulating a plurality of polypropylene filaments and locally fuse-bonding the accumulated filaments with each other at a plurality of fuse-bonding regions randomly located in the web. The filament web had a basis weight of 30 g/m$^2$ and the filaments had a thickness of 2.5 denier (2.5 x 10/9 d tex). On the surface of the filament web, a paper sheet free from fibers other than pulp fibers was laminated. This paper sheet had a wet tensile strength of 0.12 kg/25 mm, a basis weight of 20 g/m$^2$ measured in accordance with JIS P 8124, and an apparent density of 0.49 g/cm$^3$. This paper sheet was one produced from bleached soft wood kraft pulp by a wet paper-forming method. The laminate was placed on the same conveyor belt as in Comparative Example 5 in such a condition that the filament web layer came into contact with the conveyor belt and the upper surface of the paper sheet layer is exposed above.

The laminate was converted to a nonwoven fabric in the same manner as in Comparative Example 5.

The resultant nonwoven fabric did not have perforations (throughholes) having a cross-sectional area of 0.01 mm$^2$ or more.

The nonwoven fabric had a smooth surface and did not have a gauze-like appearance.

The test results are shown in Table 2.

Comparative Example 8

The same filament web as in Example 5 was subjected to the above-mentioned tests.

The test results are shown in Table 2. This filament web had poor water absorption and water retention and could not be utilized as a wiping material under wet conditions.

Comparative Example 9

The same paper sheet as in Example 5 was subjected to the above-mentioned tests.

The test results are shown in Table 2. Although this paper sheet had high water absorption, the paper sheet was easily damaged when rubbed under wet conditions and thus could not be used as a wiping material.

Table 2

| Item | | Appearance | Softness | Water absorption | Water retention | Wiping performance | Repeated useability |
|---|---|---|---|---|---|---|---|
| Example No. | | | (class) | (class) | (%) | (class) | (class) |
| Example | 4 | Gauze-like | 5 | 5 | 130 | 5 | 5 |
| | 5 | " | 4 | 5 | 180 | 5 | 4 |
| | 6 | " | 5 | 5 | 140 | 5 | 5 |
| | 7 | " | 5 | 5 | 100 | 5 | 5 |
| | 8 | " | 5 | 5 | 110 | 5 | 5 |
| Comparative Example | 5 | Non-gauze-like | 2 | 5 | 130 | 2 | 5 |
| | 6 | " | 3 | 2 | 50 | 2 | 3 |
| | 7 | " | 2 | 3 | 60 | 2 | 4 |
| | 8 | " | 3 | 1 | 0 | 1 | 4 |
| | 9 | " | 2 | 5 | 120 | 2 | 1 |

Table 2 clearly shows that the nonwoven fabrics of Examples 4 to 8 had a gauze-like appearance and a satisfactory degree of softness, water absorption, water retention, wiping performance and repeated useabil-

ity, and thus are useful as a wiping material.

The nonwoven fabrics of Comparative Examples 5 and 7 did not have perforations having a cross-sectional area of from 0.01 to 4 mm$^2$, and thus exhibited a low degree of softness and an unsatisfactory wiping performance.

The nonwoven fabric of Comparative Example 6 had perforations having a cross-sectional area of more than 4 mm$^2$, and thus exhibited poor water absorption and water retention and an unsatisfactory wiping performance.

The filament web of Comparative Example 8 had very low water absorption and water retention and thus was not useable as a wiping sheet.

The paper sheet of Comparative could not be used repeatedly as a wiping material.

Example 9

A filament web was prepared by randomly accumulating a plurality of polypropylene filaments and locally fuse-bonding the accumulated filaments with each other at a plurality of fuse-bonding regions randomly located in the web. The filament web had a basis weight of 10 g/m$^2$ and the filaments had a thickness of 2.5 denier (2.5 x 10/9 d tex). On the surface of the filament web, a paper sheet free from fibers other than pulp fibers was laminated. This paper sheet had a wet tensile strength of 0.55 kg/25 mm, a basis weight of 40 g/m$^2$ measured in accordance with JIS P 8124, and an apparent density of 0.48 g/m$^3$ measured in accordance with JIS P 8118. This paper sheet was produced from bleached softwood kraft pulp by a wet paper-forming method. The laminate was placed on a conveyor belt in such a condition that the filament web layer came into contact with the conveyor belt and the upper surface of the paper sheet layer is exposed above.

A plurality of water jet streams were spouted through a jet nozzle having a plurality of jetting holes with an inside diameter of 0.2 mm arranged in a distribution density of 16 holes/cm in the longitudinal and transversal directions thereof, under a pressure of 50 kg/cm$^2$, toward the upper surface of the paper sheet, while moving the conveyor belt at a speed of 20 m/min. The laminate was imparted with an energy of 0.32 kWh per kg of the laminate. The water jet streams passed through the laminate and conveyor belt and were discharged through the lower surface of the conveyor belt. By the above-mentioned application of the high pressure water jet streams, the pulp fibers of the paper sheet were intertwined with the filaments of the filament web, to form a nonwoven fabric.

The resultant nonwoven fabric had a back surface that derived from the filament web and partially covered by portions of the pulp fibers extending through the back surface at a total covering area corresponding to 10% of the entire surface area of the back surface.

The test results are shown in Table 3.

Example 10

A filament web was prepared by randomly accumulating a plurality of polyethylene terephthalate filaments and locally fuse-bonding the accumulated filaments with each other at a plurality of fuse-bonding regions randomly located in the web. The filament web had a basis weight of 15 g/m$^2$ and the filaments had a thickness of 2.0 denier (2.0 x 10/9 d tex). On the surface of the filament web, a paper sheet free from fibers other than pulp fibers was laminated. This paper sheet had a wet tensile strength of 0.55 kg/25 mm, a basis weight of 40 g/m$^2$ measured in accordance with JIS P 8124, and an apparent density of 0.49 g/cm$^3$ measured in accordance with JIS P 8118. This paper sheet was one produced from bleached softwood kraft pulp by a wet paper-forming method. The laminate was placed on a conveyor belt in such a condition that the filament web layer came into contact with the conveyor belt and the upper surface of the paper sheet layer is exposed above.

A plurality of water jet streams were spouted through a jet nozzle having a plurality of jetting holes with an inside diameter of 0.12 mm arranged in a distribution density of 16 holes/cm in the longitudinal and transversal directions thereof, under a pressure of 80 kg/cm$^2$, toward the upper surface of the paper sheet, while moving the conveyor belt at a speed of 17 m/min. The energy imparted to the laminate was 0.8 kWh per kg of the laminate. The water jet streams passed through the laminate and conveyor belt and were discharged through the lower surface of the conveyor belt. By the above-mentioned application of the high pressure water jet streams, the pulp fibers of the paper sheet were intertwined with the filaments of the filament web, to form a nonwoven fabric.

The resultant nonwoven fabric had a back surface that derived from the filament web and covered by portions of the pulp fibers extending through the back surface at a total covering area corresponding to 20% of the entire area of the back surface.

The test results are shown in Table 3.

Example 11

A filament web was prepared by randomly accumulating a plurality of polypropylene filaments and locally fuse-bonding the accumulated filaments with each other at a plurality of fuse-bonding regions randomly located in the web. The filament web had a basis weight of 25 g/m² and the filaments had a thickness of 3.0 denier (3.0 x 10/9 d tex). On a surface of the filament web, a paper sheet free from fibers other than pulp fibers was laminated. This paper sheet had a wet tensile strength of 0.48 kg/25 mm, a basis weight of 40 g/m² measured in accordance with JIS P 8124, and an apparent density of 0.52 g/m³ measured in accordance with JIS P 8118. This paper sheet was one produced from a blend of 80% by weight of bleached soft wood kraft pulp with 20% by weight of bleached hard wood kraft pulp, by a wet paper-forming method. The laminate was placed on a conveyor belt in such a condition that the filament web layer came into contact with the conveyor belt and the upper surface of the paper sheet layer is exposed above.

A plurality of water jet streams were spouted through a jet nozzle having a plurality of jetting holes with an inside diameter of 0.15 mm arranged in a distribution density of 10 holes/cm in the longitudinal and transversal directions thereof, under a pressure of 60 kg/cm², toward the upper surface of the paper sheet, while moving the conveyor belt at a speed of 20 m/min. The energy imparted to the laminate was 0.4 kWh per kg of the laminate. The water jet streams passed through the laminate and the conveyor belt and were discharged through the lower surface of the conveyor belt.

By the above-mentioned application of the high pressure water jet streams, the pulp fibers of the paper sheet were intertwined with the filaments of the filament web, to form a nonwoven fabric.

The resultant nonwoven fabric had a back surface derived from the filament web and partially covered by portions of the pulp fibers extending through the back surface at a total covering area corresponding to 6% of the entire surface area of the back surface.

Example 12

A filament web was prepared by randomly accumulating a plurality of polypropylene filaments and locally fuse-bonding the accumulated filaments with each other at a plurality of fuse-bonding regions randomly located in the web. The filament web had a basis weight of 15 g/m² and the filaments had a thickness of 2.5 denier (2.5 x 10/9 d tex). On a surface of the filament web, a paper sheet free from fibers other than pulp fibers was laminated. This paper sheet had a wet tensile strength of 0.25 kg/25 mm, a basis weight of 50 g/m² measured in accordance with JIS P 8124, and an apparent density of 0.61 g/m³ measured in accordance with JIS P 8118. This paper sheet was produced from bleached soft wood kraft pulp by a wet paper-forming method. The laminate was placed on a conveyor belt in such a condition that the filament web layer came into contact with the conveyor belt and the upper surface of the paper sheet layer is exposed above.

A plurality of water jet streams were spouted through a jet nozzle having a plurality of jetting holes with an inside diameter of 0.12 mm arranged in a distribution density of 16 holes/cm in the longitudinal and transversal directions thereof, under a pressure of 40 kg/cm², toward the upper surface of the paper sheet, while moving the conveyor belt at a speed of 30 m/min. The energy imparted to the laminate was 0.15 kWh per kg of the laminate. The water jet streams passed through the laminate and the conveyor belt and were discharged through the lower surface of the conveyor belt.

By the above-mentioned application of the high pressure water jet streams, the pulp fibers of the paper sheet were intertwined with the filaments of the filament web, to form a nonwoven fabric.

The resultant nonwoven fabric had a back surface derived from the filament web and partially covered by portions of the pulp fibers extending through the back surface at a total covering area corresponding to 4% of the entire area of the back surface.

The test results are shown in Table 3.

Example 13

A filament web was prepared by randomly accumulating a plurality of polypropylene filaments and locally fuse-bonding the accumulated filaments with each other at a plurality of fuse-bonding regions randomly located in the web. The filament web had a basis weight of 15 g/m² and the filaments had a thickness of 2.5 denier (2.5 x 10/9 d tex). On a surface of the filament web, a paper sheet free from fibers other than pulp fibers was laminated. This paper sheet had a wet tensile strength of 0.8 kg/25 mm, a basis weight of 80 g/m² measured in accordance with JIS P 8124, and an apparent density of 0.54 g/m³ measured in accordance with JIS P 8118. This paper sheet was one produced from bleached soft wood kraft pulp by a wet paper-forming method. The laminate was placed on a conveyor belt in such a condition that the filament web layer came into contact with

the conveyor belt and the upper surface of the paper sheet layer is exposed above.

A plurality of water jet streams were spouted through a jet nozzle having a plurality of jetting holes with an inside diameter of 0.15 mm arranged in a distribution density of 10 holes/cm in the longitudinal and transversal directions thereof, under a pressure of 80 kg/cm², toward the upper surface of the paper sheet, while moving the conveyor belt at a speed of 22 m/min. The energy imparted to the laminate was 0.6 kWh per kg of the laminate. The water jet streams passed through the laminate and conveyor belt and were discharged through the lower surface of the conveyor belt.

By the above-mentioned application of the high pressure water jet streams, the pulp fibers of the paper sheet were intertwined with the filaments of the filament web, to form a nonwoven fabric.

The resultant nonwoven fabric had a back surface derived from the filament web and partially covered by portions of the pulp fibers extending through the back surface at a total covering area corresponding to 16% of the entire area of the back surface.

The test results are shown in Table 3.

Comparative Example 10

The same procedures as in were carried out except that the pressure of the water jet streams was 15 kg/cm², and the energy imparted to the laminate was 0.05 kWh per kg of the laminate.

The back surface of the resultant nonwoven fabric was covered with portions of the pulp fibers at a total covering area corresponding to 1% of the entire area of the back surface.

The test results are shown in Table 3.

Comparative Example 11

The same procedures as in Example 10 were carried out except that the pressure of the water jet streams was 15 kg/cm², and the energy imparted to the laminate was 0.08 kWh per kg of the laminate.

The total covering area of portions of the pulp fibers extending over the back surface of the resultant nonwoven fibers was 1% or less based on the entire area of the back surface.

The test results are shown in Table 3.

Comparative Example 12

A filament web was prepared by randomly accumulating a plurality of polypropylene filaments and locally fuse-bonding the accumulated filaments with each other at a plurality of fuse-bonding regions randomly located in the web. The filament web had a basis weight of 40 g/m² and the filaments had a thickness of 2.3 denier (2.3 x 10/9 d tex). On a surface of the filament web, a paper sheet free from fibers other than pulp fibers was laminated. This paper sheet had a wet tensile strength of 0.15 kg/25 mm, a basis weight of 30 g/m² measured in accordance with JIS P 8124, and an apparent density of 0.44 g/cm³ measured in accordance with JIS P 8118. The weight ratio of the filament web to the paper sheet was 1:0.75. This paper sheet was produced from a blend of 80% by weight of bleached soft wood kraft pulp with 20% by weight of bleached hard wood kraft pulp by a wet paper-forming method. The laminate was placed on a conveyor belt in such a condition that the filament web layer came into contact with the conveyor belt and the upper surface of the paper sheet layer is exposed above. The conveyor belt is made by weaving stainless steel filament yarns in a plain weave structure in warp and weft densities of 16 yarns/cm.

A plurality of water jet streams were spouted through the same jet nozzle as in Example 11 under the same conditions as in Example 11, except that the pressure of the water jet streams was 20 kg/cm², toward the upper surface of the paper sheet.

The energy impacted to the laminate was 0.08 kWh per kg of the laminate.

The resultant nonwoven fabric had a back surface thereof covered by portions of the pulp fibers at a total covering area of 1% or less based on the entire area of the back surface.

Table 3

| Item | | Back surface of nonwoven fabric | | Repeated useability (class) | Softness (class) |
|---|---|---|---|---|---|
| Example No. | | Water absorption (class) | Wiping performance (class) | | |
| | | 5 | 5 | 5 | 5 |
| | 10 | 5 | 5 | 5 | 5 |
| | 11 | 5 | 5 | 5 | 5 |
| | 12 | 4 | 5 | 5 | 5 |
| | 13 | 5 | 5 | 5 | 5 |
| Comparative Example | 10 | 2 | 3 | 2 | 3 |
| | 11 | 2 | 2 | 2 | 3 |
| | 12 | 2 | 2 | 2 | 2 |

Table 3 clearly shows that the nonwoven fabrics of Examples 9 to 13 exhibited excellent water absorption and wiping performance even on the back surface thereof, and satisfactory repeated useability and softness. In each of Comparative Examples 10 to 12, the amount of pulp fibers extending through the back surface of the resultant nonwoven fabric was too small, and thus the and wiping performance and the resultant nonwoven fabric had poor repeated useability and lower degree of softness than that of Examples 9 to 13, due to the fact that the pulp fibers were not fully released from each other and intertwined with the filaments.

Example 14

A filament web was prepared by randomly accumulating a plurality of polypropylene filaments having a thickness of 2.5 denier (2.5 x 10/9 d tex) and heat-pressed between a heating roll having a roughened peripheral surface and a plane roll at a temperature of 130°C so as to locally fuse-bonded the filaments with each other by the protruding points of the surface-roughened heating roll. The resultant filament web had a plurality of fuse-bonded regions spaced from each other and substantially evenly distributed therein. In these regions, the filaments were fuse-bonded with each other and each fuse-bonding region had an area of 0.3 mm². The total area of the fuse-bonding regions corresponded to 7% of the entire area of the web surface. This filament web had a basis weight of 20 g/m². On a surface of the filament web, a paper sheet free from fibers other than pulp fibers was laminated. This paper sheet had a wet tensile strength of 0.33 kg/25 mm, a basis weight of 40 g/m² measured in accordance with JIS P 8124, and an apparent density of 0.50 g/cm³ measured in accordance with JIS P 8118. This paper sheet was one produced from bleached soft wood kraft pulp by a wet paper-forming method. The laminate was placed on a conveyor belt made from a metal wire net in such a manner that the filament web layer came into contact with the conveyor belt and the upper surface of the paper sheet layer is exposed above.

A plurality of water jet streams were spouted through a jet nozzle having a plurality of jetting holes with an inside diameter of 0.1 mm arranged at intervals of 1 mm in the longitudinal and transversal directions thereof, under a pressure of 50 kg/cm², toward the upper surface of the paper sheet, while moving the conveyor belt at a speed of 30 m/min. The water jet streams passed through the laminate and conveyor belt and were discharged through the lower surface of the conveyor belt. By the above-mentioned application of the high pressure water jet streams, the pulp fibers of the paper sheet were intertwined with the filaments of the filament web, to form a nonwoven fabric.

Example 15

A filament web was prepared by randomly accumulating a plurality of polypropylene terephthalate filaments having a thickness of 2.3 denier (2.3 x 10/9 d tex) and heat-pressed between a heating roll having a roughened peripheral surface and a plane roll at a temperature of 230°C so as to locally fuse-bond the filaments with each other by the protruding points of the surface-roughened heating roll. The resultant filament web had

a plurality of fuse-bonding regions spaced from each other and substantially evenly distributed therein. In this regions, the filaments were fuse-bonded with each other and each fuse-bonding region had an area of 0.09 $mm^2$ and the total area of the fuse-bonding regions corresponded to 10% of the entire area of the web surface. This filament web had a basis weight of 20 $g/m^2$. On a surface of the filament web, a paper sheet free from fibers other than pulp fibers was laminated. This paper sheet had a wet tensile strength of 0.24 kg/25 mm, a basis weight of 30 $g/m^2$ measured in accordance with JIS P 8124, and an apparent density of 0.42 $g/cm^3$ measured in accordance with JIS P 8118. This paper sheet was one produced from a bleached soft wood kraft pulp by a wet paper-forming method. The laminate was placed on a conveyor belt made from a metal wire net in such a manner that the filament web layer came into contact with the conveyor belt and the upper surface of the paper sheet layer is exposed above.

A plurality of water jet streams were spouted through a jet nozzle having a plurality of jetting holes with an inside diameter of 0.1 mm arranged at intervals of 1 mm in the longitudinal and transversal directions thereof, under a pressure of 60 $kg/cm^2$, toward the upper surface of the paper sheet, while moving the conveyor belt at a speed of 30 m/min. The water jet streams passed through the laminate and conveyor belt and were discharged through the lower surface of the conveyor belt. By the above-mentioned application of the high pressure water jet streams, the pulp fibers of the paper sheet were intertwined with the filaments of the filament web, to form a nonwoven fabric.

Example 16

A filament web was prepared by randomly accumulating a plurality of polypropylene filaments having a thickness of 3.3 denier (3.3 x 10/9 d tex) and heat-pressed between a heating roll having a roughened peripheral surface and a plane roll at a temperature of 130°C so as to locally fuse-bond the filaments with each other by the protruding points of the surface-roughened heating roll. The resultant filament web had a plurality of fuse-bonding regions spaced from each other and substantially evenly distributed therein. In this regions, the filaments were fuse-bonded with each other and each fuse-bonding region had an area of 2.0 $mm^2$. The total area of the fuse-bonding regions corresponded to 6% of the entire area of the web surface. This filament web had a basis weight of 15 $g/m^2$. On a surface of the filament web, a paper sheet free from fibers other than pulp fibers was laminated. This paper sheet had a wet tensile strength of 0.28 kg/25 mm, a basis weight of 30 $g/m^2$ measured in accordance with JIS P 8124, and an apparent density of 0.42 $g/cm^3$ measured in accordance with JIS P 8118. This paper sheet was one produced from a blend of 80% by weight of bleached soft wood kraft pulp with 20% by weight of bleached hard wood kraft pulp by a wet paper-forming method. The laminate was placed on a conveyor belt in such a manner that the filament web layer came into contact with the conveyor belt and the upper surface of the paper sheet layer is exposed above.

A plurality of water jet streams were spouted through a jet nozzle having a plurality of jetting holes with an inside diameter of 0.1 mm arranged at intervals of 1 mm in the longitudinal and transversal directions thereof, under a pressure of 40 $kg/cm^2$, toward the upper surface of the paper sheet, while moving the conveyor belt at a speed of 30 m/min. The water jet streams passed through the laminate and conveyor belt and were discharged through the lower surface of the conveyor belt. By the above-mentioned application of the high pressure water jet streams, the pulp fibers of the paper sheet were intertwined with the filaments of the filament web, to form a nonwoven fabric.

Example 17

A filament web was prepared by randomly accumulating a plurality of polypropylene filaments having a thickness of 1.5 denier (1.5 x 10/9 d tex) and heat-pressed between a heating roll having a roughened peripheral surface and a plane roll at a temperature of 130°C so as to locally fuse-bond the filaments with each other by the protruding points of the surface-roughened heating roll. The resultant filament web had a plurality of fuse-bonding regions spaced from each other and substantially evenly distributed therein. In this regions, the filaments were fuse-bonded with each other and each fuse-bonding region had an area of 0.3 $mm^2$. The total area of the fuse-bonding regions corresponded to 15% of the entire area of the web surface. This filament web had a basis weight of 15 $g/m^2$. On a surface of the filament web, a paper towel free from fibers other than pulp fibers was laminated. This paper towel had a wet tensile strength of 0.1 kg/25 mm, a basis weight of 22 $g/m^2$ measured in accordance with JIS P 8124, and an apparent density of 0.28 $g/cm^3$ measured in accordance with JIS P 8118. This paper towel was one produced from bleached soft wood kraft pulp by a wet paper-forming method. The laminate was placed on a conveyor belt made from a metal wire net in such a manner that the filament web layer came into contact with the conveyor belt and the upper surface of the paper towel layer is exposed above.

A plurality of water jet streams were spouted through a jet nozzle having a plurality of jetting holes with an inside diameter of 0.1 mm arranged at intervals of 1 mm in the longitudinal and transversal directions thereof, under a pressure of 40 kg/cm², toward the upper surface of the paper towel, while moving the conveyor belt at a speed of 30 m/min. The water jet streams passed through the laminate and conveyor belt and were discharged through the lower surface of the conveyor belt. By the above-mentioned application of the high pressure water jet streams, the pulp fibers of the paper towel were intertwined with the filaments of the filament web, to form a nonwoven fabric.

Example 18

A filament web was prepared by randomly accumulating a plurality of polypropylene filaments having a thickness of 2.3 denier (2.3 x 10/9 d tex) and heat-pressed between a heating roll having a roughened peripheral surface and a plane roll at a temperature of 130°C so as to locally fuse-bond the filaments with each other by the protruding points of the surface-roughened heating roll. The resultant filament web had a plurality of fuse-bonding regions spaced from each other and substantially evenly distributed therein. In this regions, the filaments were fuse-bonded with each other and each fuse-bonding region had an area of 0.28 mm². The total area of the fuse-bonding regions corresponded to 3% of the entire area of the web surface. This filament web had a basis weight of 15 g/m². On a surface of the filament web, a paper sheet free from fibers other than pulp fibers was laminated. This paper sheet had a wet tensile strength of 0.66 kg/25 mm, a basis weight of 70 g/m² measured in accordance with JIS P 8124, and an apparent density of 0.50 g/cm³ measured in accordance with JIS P 8118. This paper sheet was one produced from bleached soft wood kraft pulp by a wet paper-forming method. The laminate was placed on a conveyor belt made from a metal wire net in such a manner that the filament web layer came into contact with the conveyor belt and the upper surface of the paper sheet layer is exposed above.

A plurality of water jet streams were spouted through a jet nozzle having a plurality of jetting holes with an inside diameter of 0.1 mm arranged at intervals of 1 mm in the longitudinal and transversal directions thereof, under a pressure of 80 kg/cm², toward the upper surface of the paper sheet, while moving the conveyor belt at a speed of 30 m/min. The water jet streams passed through the laminate and conveyor belt and were discharged through the lower surface of the conveyor belt. By the above-mentioned application of the high pressure water jet streams, the pulp fibers of the paper sheet were intertwined with the filaments of the filament web, to form a nonwoven fabric.

In the Examples 14 to 18, the water discharged through the lower surface of the conveyor belt was recovered and reused for the water jet streams. It was also confirmed that the resultant nonwoven fabrics of Examples 14 to 18 had satisfactory softness and tactile quality, excellent water absorption and water retention, and even when the nonwoven fabrics were rubbed on a desk surface under wet conditions, they exhibited a high resistances to tearing, to separation of the filament web layer from the paper sheet layer and to releasing of the pulp fiber. Also, the nonwoven fabric could be repeatedly used and rinsed with water, without tearing.

Comparative Example 13

The same procedures as in Example 14 were carried out except that the fuse-bonding regions of the filament web had an area of 0.006m² and the total area of the fuse-bonding regions in the filament web corresponded to 4% of the entire area of the filament web surface.

The water discharged through the lower surface of the conveyor belt was recovered and reused for the water jet streams. It was found that the amount of the pulp fibers contained in the recovered water was larger than that in Examples 14 to 18. In this comparative example, the filaments in the filament web were fuse-bonded at the fuse-bonding regions having a very small fuse-bonding area and thus the fuse-bonding strength of the filaments was relatively low. Accordingly, when the high pressure water jet streams were applied, the filaments in the filament web were opened so as to form a number of large gaps between the filaments, and a portion of the pulp fibers were discharged to the outside of the laminate through the gaps.

The resultant nonwoven fabric exhibited an unsatisfactory tensile strength and was easily damaged by strongly rubbing a desk surface with the fabric.

Comparative Example 14

The same procedures as in Example 14 were carried out except that the fuse-bonding regions of the filament web had an individual area of 6 mm² and the total area corresponding to 15% of the entire area of the filament web surface.

The resultant nonwoven fabric had a plurality of portions thereof in which the pulp fibers were not fully intertwined with the filaments due to the excessively large area of the fuse-bonding regions, and thus during use of the nonwoven fabric as a wiping material, a portion of the pulp fibers was removed from the fabric.

Comparative Example 15

The same procedures as in Example 14 were carried out except that the fuse-bonding regions of the filament web had an individual area of 0.6 $mm^2$ and a total area corresponding to 30% of the entire area of the filament web surface.

Due to the fact that the total area of the fuse-bonding regions in the filament web was too large, the filaments in the web had a low degree of freedom in relative movement to each other, and the pulp fibers were not fully intertwined with the filaments. The non-intertwined pulp fibers were easily removed from the fabric when the fabric was employed as a wiping fabric.

Example 19

A filament web was prepared by randomly accumulating a plurality of polypropylene filaments and locally fuse-bonding the accumulated filaments with each other at a plurality of fuse-bonding regions randomly located in the web. The filament web had a basis weight of 15 $g/m^2$ and the filaments had a thickness of 2.2 denier (2.2 x 10/9 d tex). On a surface of the filament web, a paper sheet free from fibers other than pulp fibers was laminated. This paper sheet had a wet tensile strength of 0.54 kg/25 mm, a basis weight of 60 $g/m^2$ measured in accordance with JIS P 8124, and an apparent density of 0.55 $g/cm^3$ measured in accordance with JIS P 8118. This paper sheet was one produced from bleached soft wood kraft pulp having a Canadian Standard Freeness of 620 ml determined in accordance with JIS P 8121, by a wet paper-forming method. The laminate was placed on a conveyor belt made from a metal wire net in such a manner that the filament web layer came into contact with the conveyor belt and the upper surface of the paper sheet layer is exposed above.

A plurality of water jet streams were spouted through a jet nozzle having a plurality of jetting holes with an inside diameter of 0.12 mm arranged in intervals of 0.64 mm in the longitudinal and transversal directions thereof, under a pressure of 70 $kg/cm^2$, toward the upper surface of the paper sheet, while moving the conveyor belt at a speed of 20 m/min. During the above-mentioned water-spouting operation, the spouted water did not remain on the upper surface of the paper sheet layer. The water jet streams passed through the laminate and conveyor belt and were discharged through the lower surface of the conveyor belt. By the above-mentioned application of the high pressure water jet streams, the pulp fibers of the paper sheet were intertwined with the filaments of the filament web, to form a nonwoven fabric.

The test results are shown in Table 4.

Example 20

A filament web was prepared by randomly accumulating a plurality of polyethylene terephthalate filaments and locally fuse-bonding the accumulated filaments with each other at a plurality of fuse-bonding regions randomly located in the web. The filament web had a basis weight of 15 $g/m^2$ and the filaments had a thickness of 2.3 denier (2.3 x 10/9 d tex). On a surface of the filament web, a paper sheet free from fibers other than pulp fibers was laminated. This paper sheet had a wet tensile strength of 0.38 kg/25 mm, a basis weight of 40 $g/m^2$ measured in accordance with JIS P 8124, and an apparent density of 0.53 $g/cm^3$ measured in accordance with JIS P 8118. This paper sheet was one produced from a blend of bleached soft wood kraft pulp having a Canadian Standard Freeness of 660 ml and 20% by weight of bleached hard wood kraft pulp having a Canadian Standard Freeness of 630 ml, by a wet paper-forming method. The laminate was placed on a conveyor belt made from a metal wire net in such a manner that the filament web layer came into contact with the conveyor belt and the upper surface of the paper sheet layer is exposed above.

A plurality of water jet streams were spouted through a jet nozzle having a plurality of jetting holes with an inside diameter of 0.12 mm arranged at intervals of 0.64 mm in the longitudinal and transversal directions thereof, under a pressure of 50 $kg/cm^2$, toward the upper surface of the paper sheet, while moving the conveyor belt at a speed of 20 m/min. During the water spouting operation, the spouted water did not remain on the upper surface of the laminate. The water jet streams passed through the laminate and conveyor belt and were discharged through the lower surface of the conveyor belt. By the above-mentioned application of the high pressure water jet streams, the pulp fibers of the paper sheet were intertwined with the filaments of the filament web, to form a nonwoven fabric.

The test results are shown in Table 4.

Example 21

A filament web was prepared by randomly accumulating a plurality of polypropylene filaments and locally fuse-bonding the accumulated filaments with each other at a plurality of fuse-bonding regions randomly located in the web. The filament web had a basis weight of 10 g/m$^2$ and the filaments had a thickness of 2.2 denier (2.2 x 10/9 d tex). On a surface of the filament web, a paper sheet free from fibers other than pulp fibers was laminated. This paper sheet had a wet tensile strength of 0.40 kg/25 mm, a basis weight of 50 g/m$^2$ measured in accordance with JIS P 8124, and an apparent density of 0.49 g/cm$^3$ measured in accordance with JIS P 8118. This paper sheet was one produced from unbeaten, bleached soft wood kraft pulp having a Canadian Standard Freeness of 690 ml, by a wet paper-forming method. The laminate was placed on a conveyor belt made from a metal wire net in such a manner that the filament web layer came into contact with the conveyor belt and the upper surface of the paper sheet layer is exposed above.

A plurality of water jet streams were spouted through a jet nozzle having a plurality of jetting holes with an inside diameter of 0.15 mm arranged at intervals of 1 mm in the longitudinal and transversal directions thereof, under a pressure of 60 kg/cm$^2$, toward the upper surface of the paper sheet, while moving the conveyor belt at a speed of 20 m/min. During the water-spouting operation, the spouted water did not remain on the laminate surface to form pools. The water jet streams passed through the laminate and conveyor belt and were discharged through the lower surface of the conveyor belt. By the above-mentioned application of the high pressure water jet streams, the pulp fibers of the paper sheet were intertwined with the filaments of the filament web, to form a nonwoven fabric.

The test results are shown in Table 4.

Comparative Example 16

The same procedures as in Example 19 were carried out except that the paper sheet was prepared from bleached soft wood kraft pulp having a Canadian Standard Freeness of 550 ml determined in accordance with JIS P 8121 and had a wet tensile strength of 0.59 kg/25 mm.

During the water-spouting operation, portions of the spouted water resided on the laminate surface to form pools. The water jet streams struck the residing water on the laminate surface and were scattered to the ambient atmosphere.

The test results are shown in Table 4.

Comparative Example 17

The same procedures as in Example 19 were carried out except that the bleached soft wood draft pulp had a Canadian Standard Freeness of 510 ml measured in accordance with JIS P 8124 and the paper sheet had a wet tensile strength of 0.47 kg/25 mm and a basis weight of 40 g/m$^2$.

In the water-spouting step, a portion of the spouted water resided on the laminate surface and was scattered by being struck with the water jet streams.

The test results are shown in Table 4.

Comparative Example 18

The same filament web as in Example 19 was subjected to the tests.

The test results are shown in Table 4.

Comparative Example 19

The same paper sheet as in Example 19 was subjected to the tests.

The test results are shown in Table 4.

Table 4

| Item | | Water absorption | Wiping performance | softness | Repeated useability | Surface (ground evenness) |
|---|---|---|---|---|---|---|
| Example No. | | (class) | (class) | (class) | (class) | (class) |
| Example | 19 | 5 | 5 | 5 | 5 | 5 |
| | 20 | 5 | 5 | 5 | 5 | 5 |
| | 21 | 5 | 5 | 5 | 5 | 5 |
| Comparative Example | 16 | 3 | 4 | 2 | 2 | 3 |
| | 17 | 2 | 4 | 2 | 2 | 3 |
| | 18 | 1 | 1 | 4 | 5 | 2 |
| | 19 | 5 | 4 | 2 | 1 | 5 |

Table 4 shows that the nonwoven fabrics of Examples 19 to 21 in accordance with the present invention, exhibited excellent water absorption, wiping performance, softness, repeated useability and surface (ground) evenness, and thus were useful as a wiping material sheet. In comparative Examples 16 and 17, the pulp fibers were fully released from each other due to a low Canadian Standard freeness thereof even by the application of the high pressure water jet streams and thus the filaments were not fully intertwined by the pulp fibers, and thus the resultant nonwoven fabrics exhibited a low degree of softness and repeated useability and lower water absorption, wiping performance and surface evenness than those of Examples 19 to 21. Also, in the Comparative Examples 16 and 17, a portion of water resided on the laminate surface and was scattered and adhered to the surface of the resultant nonwoven fabric. The scattered water contained pulp fibers in a relatively high concentration. Therefore, the adhesion of the scattered water causes the resultant nonwoven fabric to exhibit a lowered surface (ground) evenness.

In comparative Examples 18 and 19, it was confirmed that the filament web per se had very poor water absorption and wiping performance and poor surface evenness, and the paper sheet per se had a low degree of softness and very poor repeated useability.

Example 22

A filament web was prepared by randomly accumulating a plurality of polypropylene filaments and locally fuse-bonding the accumulated filaments with each other at a plurality of fuse-bonding regions randomly located in the web. The polypropylene filaments had an individual filament thickness of 2.5 denier (2.5 x 10/9 d tex), and the filament web had a basis weight of 20 g/m$^2$.

A paper sheet was produced from bleached soft wood kraft pulp fibers mixed with a polyamide-epichlorohydrin resin in an amount of 0.3 part by weight per 100 parts by bone-dry weight of the bleached soft wood kraft pulp fibers, by a wet paper-forming method. This paper sheet had a wet tensile strength of 1.1 kg/25 mm width determined by using a specimen with a width of 25 mm in accordance with JIS P8135, and a basis weight of 60 g/m$^2$ determined in accordance with JIS P 8124.

The paper sheet was laminated on a surface of the filament web.

The laminate was placed on a conveyor belt made from a metal wire net in such a condition that the paper sheet is located on the filament web.

A plurality of high pressure water jet streams formed by spouting water through a jet nozzle having a plurality of jetting holes having an inside diameter of 0.12 mm and arranged at intervals of 0.64 mm in the longitudinal and transversal directions thereof, under a pressure of 70 kg/cm$^2$ were applied to the paper sheet layer surface of the laminate, while moving the laminate on the conveyor belt at a speed of 20 m/min.

The pulp fibers of the paper sheet penetrate the filament web and intertwine with the filaments to form a nonwoven fabric that is useful as a wiping material.

The test results are shown in Table 5.

Example 23

A filament web was prepared by randomly accumulating a plurality of polyethylene terephthalate filaments and locally fuse-bonding the polyethylene terephthalate filaments with each other at a plurality of fuse-bonding regions randomly located in the web. The filaments in the filament web had a thickness of 2.3 denier (2.3 x 10/9 d tex) and the filament web had a basis weight of 15 g/m$^2$.

A paper sheet was produced from a mixture of 80% by weight of bleached soft wood kraft pulp fibers, 20% by weight of bleached hard wood kraft pulp fibers and a polyamide-epichlorohydrin resin in an amount of 0.5 part by weight per 100 parts by total bone-dry weight of the bleached soft and hard wood kraft pulp fibers, by a wet paper-forming method.

This paper sheet had a wet tensile strength of 0.70 kg/25 mm width, measured in accordance with JIS P8135, and a basis weight of 35 g/m$^2$ measured in accordance with JIS P8124.

The paper sheet was laminated on a surface of the filament web to form a laminate.

The laminate was placed on a conveyor belt made from a metal wire net in such a condition that the paper sheet was located on the filament web.

A plurality of high pressure water jet streams formed by spouting water through a jet nozzle having a plurality of jetting holes with an inside diameter of 0.12 mm and arranged at intervals of 0.64 mm in the longitudinal and transversal directions thereof, under a pressure of 50 kg/cm$^2$, were applied to the paper sheet layer surface of the laminate, while moving the laminate on the conveyor belt at a speed of 20 m/min.

The pulp fibers of the paper sheets penetrated the filament web and intertwined with the filaments to form a nonwoven fabric useful as a wiping material.

The test results are shown in Table 5.

Example 24

A filament web was prepared by randomly accumulating a plurality of polypropylene filaments and locally fuse-bonding the polypropylene filaments with each other at a plurality of fuse-bonding regions randomly located in the web. The filaments in the filament web had a thickness of 2.5 denier (2.0 x 10/9 d tex) and the filament web had a basis weight of 10 g/m$^2$.

A paper sheet was produced from bleached soft wood kraft pulp fibers mixed with a polyamide-epichlorohydrin resin in an amount of 0.3 part by weight per 100 parts by bone-dry weight of the bleached soft wood kraft pulp fibers, by using a wet paper-forming method.

This paper sheet had a wet tensile strength of 0.8 kg/25 mm width, measured in accordance with JIS P 8135, and a basis weight of 35 g/m$^2$ measured in accordance with JIS P8124.

The paper sheet was laminated on a surface of the filament web to form a laminate.

The laminate was placed on a conveyor belt made from a metal wire net in such a condition that the paper sheet was located above the filament web.

A plurality of high pressure water jet streams formed by spouting water through a jet nozzle having a plurality of jetting holes with an inside diameter of 0.12 mm and arranged at intervals of 1 mm under a pressure of 60 kg/cm$^2$, were applied to the paper sheet layer surface of the laminate, while moving the laminate on the conveyor belt at a speed of 20 m/min.

The pulp fibers of the paper towel penetrated the filament web and intertwined with the filaments to form a nonwoven fabric useful as a wiping material.

The test results are shown in Table 5.

Comparative Example 20

The same procedures as in Example 22 were carried out except that the paper sheet had a wet tensile strength of 0.03 kg/25 mm width and a basis weight of 40 g/m$^2$. During the application of the high pressure water jet streams, the paper sheet was often significantly damaged and the pulp fibers were scattered. Due to the damage to the paper sheet, the nonwoven fabric-forming procedure was often stopped.

The test results are shown in Table 5.

Comparative Example 21

The same procedures as in Example 22 were carried out except that the paper sheet had a wet tensile strength of 1.8 kg/25 mm and a basis weight of 80 g/m$^2$.

During the application of the water jet streams, portions of the spouted water resided on the laminate sur-

face to form pools. The water jet streams struck the residing water on the laminate surface and were scattered into the ambient atmosphere. The resultant nonwoven fabric had a rough surface, an unsatisfactory touch and a low softness.

The test results are shown in Table 5.

Comparative Example 22

The same filament web as in Example 22 was subjected, as a wiping fabric to the above-mentioned tests. The test results are shown in Table 5.

Comparative Example 23

The same paper sheet as in Example 1 was subjected to the above-mentioned tests. The test results are shown in Table 5.

| Item | | Water absorption | Wiping performance | Softness | Repeated useability | Surface evenness |
|---|---|---|---|---|---|---|
| Example No. | | (class) | (class) | (class) | (class) | (class) |
| Example | 22 | 5 | 5 | 5 | 5 | 5 |
| | 23 | 5 | 5 | 5 | 5 | 5 |
| | 24 | 5 | 5 | 5 | 5 | 5 |
| Comparative Example | 20 | 2 | 3 | 2 | 4 | 2 |
| | 21 | 2 | 2 | 2 | 4 | 2 |
| | 22 | 1 | 1 | 4 | 5 | 2 |
| | 23 | 5 | 4 | 2 | 1 | 5 |

## Claims

1. A process for producing a wiping nonwoven fabric comprising the steps of:
   laminating a paper sheet comprising pulp fibers and having a wet tensile strength of 0.04 to 1.5 kg/25 mm width determined by using a specimen having a width of 25 mm in accordance with Japanese Industrial Standard P 8135, on a surface of a filament web in which a plurality of filaments are randomly accumulated on each other; and
   applying a plurality of water jet streams toward the paper sheet layer surface of the laminate under a pressure sufficient to allow the water jet stream to penetrate the filament web layer through the paper sheet layer and to cause the pulp fibers and the filaments to intertwine with each other, thereby forming a nonwoven fabric.

2. The process as claimed in claim 1, wherein the filaments in the filament web are selected from the group consisting of rayon filaments, polyolefin filaments, polyester filaments, polyamide filaments, polyacrylic ester filaments.

3. The process as claimed in claim 1, wherein the filaments in the filament web have a thickness of 1 to 4 deniers.

4. The process as claimed in claim 1, wherein the filament web has a basis weight of 5 to 30 g/m$^2$.

5. The process as claimed in claim 1, wherein the filaments in the filament web are fuse-bonded to each other at portions of cross points thereof.

6. The process as claimed in claim 1, wherein the paper sheet has a basis weight of 10 to 100 g/m$^2$.

7. The process as claimed in claim 1, wherein the paper sheet comprises soft wood pulp fibers and hard wood pulp fibers in a basis weight ratio of 100:0 to 20:80.

8. The process as claimed in claim 1, wherein the paper sheet has an apparent density of 0.2 to 0.6 g/cm$^3$ or less.

9. The process as claimed in claim 1, wherein the filament web has a ratio in basis weight to the paper sheet of 1:1 to 1:19, determined in accordance with Japanese Industrial Standard P 8124.

10. The process as claimed in claim 1, wherein the water jet streams are jetted through nozzle holes having a hole diameter of 0.01 to 0.3 mm under a pressure of 10 to 150 kg/cm$^2$.

11. The process as claimed in claim 1, wherein the laminate consisting of the paper sheet and the filament web is superimposed on a porous support sheet; the water jet streams are applied toward the paper sheet layer surface under a pressure sufficient to allow the water jet streams to penetrate the laminated paper sheet, filament web and porous support sheet and cause the pulp fibers of the paper sheet and the filaments of the filament web to intertwine with each other; and the resultant nonwoven fabric is removed from the porous support sheet.

12. The process as claimed in claim 11, wherein the application of the water jet streams causes a plurality of perforations each having a cross-sectional area of 0.01 to 4 mm$^2$ to be formed in the resultant nonwoven fabric.

13. The process as claimed in claim 12, wherein the perforations are distributed at a distribution density of 6 to 600 perforations per cm$^2$ of the surface area of the resultant nonwoven fabric.

14. The process as claimed in claim 11, wherein the porous support sheet comprises at least one woven fabric made from a plurality of fine filament yarns.

15. The process as claimed in claim 14, wherein the fine filament yarns are selected from the group consisting of stainless steel filament yarns, bronze filament yanrs and plastics filament yarns.

16. The process as claimed in claim 14, wherein the fine filament yarns have an average thickness of 0.2 to 1.5 mm.

17. The process as claimed in claim 14, wherein the woven fabric has a warp and weft density of 3 to 36 yarns/cm.

18. The process as claimed in claim 1, wherein the laminate is imparted with a water jet stream energy of 0.1 kWh or more calculated in accordance with the equation (I):

$$E = (Q\rho V^2)/_2 \quad (I)$$

wherein E represents an energy in kWh imparted by the water jet streams, Q represents a weight of water in kg necessary to convert the laminate having a weight of 1 kg to a nonwoven fabric, V represents a flow velocity in m/sec of the water jet streams and $\rho$ represents a specific gravity of the water used.

19. The method as claimed in claim 18, wherein the application of the water jet streams causes portions of the pulp fibers to penetrate the filament web and the partially cover a surface of the filament web not brought into contact with the paper sheet, at a total covering area corresponding to 2% or more of the entire surface area of the filament web.

20. The process as claimed in claim 1, wherein the filaments in the filament web are fuse-bonded to each other at a plurality of bonding regions thereof spaced from each other; each of the bonding regions having an area of 0.01 to 4 mm$^2$ and the total area of the bonding regions corresponding to 2 to 20% of the entire surface area of the filament web.

21. The method as claimed in claim 1, wherein the paper sheet is produced from a pulp having a Canadian Standard Freeness of 600 ml or more, determined in accordance with Japanese Industrial Standard P8121, by a wet paper-forming procedure.

22. The process as claimed in claim 21, wherein the pulp is a non-beaten wood pulp.

European Patent Office

# EUROPEAN SEARCH REPORT

Application Number

EP 93 30 1738

## DOCUMENTS CONSIDERED TO BE RELEVANT

| Category | Citation of document with indication, where appropriate, of relevant passages | Relevant to claim | CLASSIFICATION OF THE APPLICATION (Int. Cl.5) |
|---|---|---|---|
| X<br>A | EP-A-0 333 211 (KIMBERLY-CLARK CORPORATION)<br>* whole document * | 1-4,6,7, 11,19<br>10,15 | D04H1/44<br>D04H13/00<br>D04H5/02 |
| P,X | EP-A-0 492 554 (KIMBERLY-CLARK CORPORATION)<br>* whole document * | 1-4,6,7, 10,11, 14,19 | |
| P,A | EP-A-0 483 816 (KIMBERLY-CLARK CORPORATION)<br>* page 9, line 6 - line 16 * | 12 | |

TECHNICAL FIELDS SEARCHED (Int. Cl.5)

D04H

The present search report has been drawn up for all claims

| Place of search | Date of completion of the search | Examiner |
|---|---|---|
| THE HAGUE | 22 JUNE 1993 | VAN BEURDEN-HOPKINS |

CATEGORY OF CITED DOCUMENTS

X : particularly relevant if taken alone
Y : particularly relevant if combined with another document of the same category
A : technological background
O : non-written disclosure
P : intermediate document

T : theory or principle underlying the invention
E : earlier patent document, but published on, or after the filing date
D : document cited in the application
L : document cited for other reasons

& : member of the same patent family, corresponding document